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# **DIRECTION OF ARRIVAL OF RADIO WAVES**

**N6-ori-71 Task XV  
ONR Project No. 076 161**



**RADIO DIRECTION FINDING RESEARCH LABORATORY  
DEPARTMENT OF ELECTRICAL ENGINEERING  
UNIVERSITY OF ILLINOIS  
URBANA, ILLINOIS**

*Incl #6*

STATUS REPORT  
ON  
DIRECTION OF ARRIVAL  
OF RADIO WAVES  
Project No. NR-076-161  
N6-ori-7115 Report No. DF 30

Date:  
30 June 1954

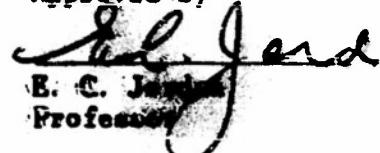
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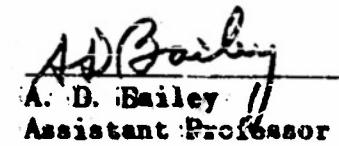
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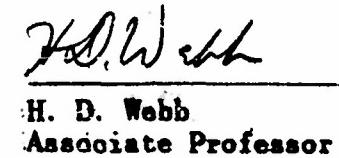
to

31 May 1954

Approved by

  
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## 1. GENERAL INFORMATION

### 1.1 Visitors

On 21 April 1954, Mr. Allen A. Kunze of the Rome Research and Development Center visited the RDF Section.

On 28 and 29 April 1954, Mr. F.D. Green and Lt. D.R. McCaskill of the Department of National Defense Headquarters, Ottawa, Canada; Mr. C.W. McLeish of the National Research Council, Ottawa, Canada; and Mr. A.T.L. Rocke, Senior Naval Liaison Officer to Canada for the United Kingdom, visited the RDF section for the purpose of discussing RDF problems of mutual interest.

On 7 May 1954, Mr. R. Lisk of Wyeth Engineering, Inc., and G.R. Billheimer of the Bureau of Ships visited the RDF section to leave a field intensity meter AN/RFM-1.

### 1.2 Personnel

On 1 April 1954, Mr. J.E. Ernest was transferred from the RDF section of the Electrical Engineering Research Laboratory to the Control Systems Laboratory.

## 2. SUMMARY STATEMENT OF PROGRESS ON THE SEVERAL PROJECTS

### 2.1 Direction of Arrival of Waves - E.C. Hayden, E.J. Dunn, R.S. Smith

During the past quarter, the antenna amplifiers and associated circuits to be installed in our CRDF system have received considerable attention. Numerous measurements have been made to evaluate the performance of the amplifiers. Noise characteristics, output impedance, gain, and sensitivity to tube changes have been measured.

It has been decided to use broad-band, ferrite-cored transformers for the difference circuits in the antenna system. Several models were constructed and tested. They were checked for band width and balance. A suitable design was evolved and two transformers were built. At present, impedance matching problems in the antenna circuits are being worked out, and overall antenna system noise factors are being calculated.

Some preliminary photographic recordings of data have been made to determine exposure times and to select the type of film best suited for the job. Within the next quarter a considerable amount of data will be obtained.

Some improvements in the photographic system have been worked out and will be installed as time permits.

### 2.2 Matched-Channel Amplifier Problems - H.D. Webb, T.R. O'Meara

An AGC detector system which gives a detector output from the N-S and E-W receiving channels that is nearly independent of the direction of arrival of the signal has been developed for use on the CRDF. The time constants in the AGC system have been modified on the basis of work by personnel of the Electrical and Radio Engineering Division, National Research Council, Ottawa, Ontario. This modification gives AGC attack times of 2, 10, 50, and 250 milliseconds. The fastest attack time previously used was 30 milliseconds. This type of AGC system has been incorporated in the three-channel radio frequency amplifier.

It has been decided to use only two band widths, a 20 kc band width centered at 455 kc and a 1 kc band width centered at 50 kc, for the initial operation of the three-channel IF amplifier. The tuned circuits for the 1 kc band width have been installed and those for the 20 kc band width have been completed and partially matched.

### **2.3 Application of Probability Theory and Statistical Inference to the Radio Direction Finding Problem - A.D. Bailey and R.L. Sydnor**

A thesis entitled, "Investigation of the Direction of Arrival of Radio Waves" by Albert D. Bailey, submitted in partial fulfillment of the requirements for a Ph.D. in Engineering, has been accepted.

Technical Report No. 20 is now being prepared. It includes the significant results of the thesis and will contain in addition a comparison of these results with those obtained by other investigators. Because of the latter comparison it will be classified.

Two Admiralty Pattern 1320-B precision goniometers have been received on loan. These will be used in the construction of the post-bearing azimuth shifter. The need for such a device was outlined in the previous status report.

The final circuits for the latest model of the bearing data computer have been fixed. This is the second modification of the original circuitry and it incorporates the best of all the development work that has been carried on for the last two years. There remains the problem of how to best perform the long-time averaging of the indicated bearing. The electro-mechanical bearing counter circuitry originally proposed has merit, and the use of a very long time constant integrating circuit also has merit. A decision between these will be made.

Bearing studies on additional propagation paths will be made during the next period.

### **2.4 Aircraft RDF and Homing Systems - W. Yaru, D.E. Royal**

The work on this project is continuing under Contract N6-ori-07137. The details of the work are given in the status reports issued under that contract. Technical Report No. 2 on some of the more recent work has been completed.

### **2.5 Application of Ionospheric Cross-Modulation in Radio Direction Finding - J.M. Anderson**

The field application of this project remains inactive. Mr. Anderson is still working on the laboratory aspects of the problem in the Electron Tube Section.

Two papers were presented during the past quarter by L. Goldstein and J.M. Anderson:

1. "Interaction of Microwaves in Gaseous Discharge Plasmas and the Ramsauer Effect," presented at the Fourteenth Annual Conference on Physical Electronics, held 25, 26, and 27 March 1954 at MIT.
2. "Interaction of Electro-Magnetic Waves in Gaseous Discharge Plasmas," presented at the URSI meeting, 4 May 1954, National Bureau of Standards, Washington, D.C.

Appendix A  
Task XV Technical Reports

1. RDF Staff. *Bibliography of Published Articles on Radio Direction Finding.*. June 1, 1947.
2. RDF Staff. *Abstracts of Published Articles on Radio Direction Finding.*. September 1, 1947.
3. (Classified). February 1, 1948.
4. RDF Staff. *Summary Technical Report.* April 15, 1948.
5. RDF Staff. *Abstracts of U.S. Patents on Radio Direction Finding.* June 1, 1948.
6. Yaru, N. *Small High-Gain Arrays for Direction Finding.* September 1, 1948.
7. Annis, R.W. *Analysis of Radio Direction Finding Systems.*, Part I. September 1, 1948.
8. Bullet, J.L.L., Anderson J.M., O'Meara, T.R. *Doppler-Type Direction Finding* October 1, 1948.
9. (Classified). December 1, 1949.
10. (Classified). August 1, 1950.
11. (Classified). November 1, 1950.
12. Myers, J.J. *Radio Direction Finder System Analyzer.* December 1, 1950.
13. (Classified). January 1, 1951.
14. DuHamel, R.H. *Patterns and Impedances of an Antenna Near a Conducting Cylinder.* September 1, 1951.
15. Fowler, V.J. *Transmission-Line Tubes.* September 1, 1951.
16. DuHamel, R.H. *Pattern Synthesis for Antenna Arrays on Circular, Elliptical, and Spherical Surfaces.* May 1952.
17. (Classified). April 1953.
18. (Classified). March 1954.
19. (Classified). January 1954.

Appendix B  
Task XV Technical Memoranda

1. Hayden, E.C., Johnk, C.T., and Anderson, J.M. *Matching H. F. Cables for Total Phase Shift.*, January 1, 1951.
2. Hayden, E.C. *Reception of Pulse Signals.*, April 3, 1951.
3. Fowler, V.J. *Selective Matching of Components.*, July 1, 1951.
4. McNabb, J.W. *Oscillator and Buffer Units.*, July 1, 1951.
5. Hayden, E.C. *CRDF Installation at U. of I. Airport.*, March 30, 1951.
6. Webb, H.D. *Percent Ellipsing and Bearing Error Due to Mismatch of Phase and Gain Characteristics in Dual Channel Receiving Systems.*, August 29, 1951.
7. Fowler, V.J. *A Crystal Stabilized Frequency Deviable Test Oscillator.*, August 23, 1951.
8. Hayden, E.C. *Radio Wave Propagation via the Ionosphere from Columbus, Ohio to Urbana, Illinois.*, August 27, 1951.
9. Hayden, E.C. *Instruction Book for Pulse Transmitter.*, October 31, 1951.
10. Anderson, J.M. *Field Installation Circuit Diagrams.*, November 1, 1951.
11. O'Meara, T.R. *IF Phase and Gain Stability.*, January 15, 1952.
12. Hayden, E.C. *Reception of Pulse Signals from the Netherlands.*, January 31, 1952.
13. Duhamel, R.H., and Yaru, N. *Technical Memorandum on the Pattern Measuring Equipment.*, February 1, 1952.
14. Anderson, J.M. *Pulse Receiver No. 2.*, February 1, 1952.
15. Hayden, E.C. *Patterns of a Typical Dipole-Cylinder Array, Including the Effects of Two Signals.*, March 24, 1952.
16. Anderson, J.M. *Polarization Error Tests of Canadian CRDF with Helicopter.*, June 3, 1951.
17. Anderson, J.M. *Progress Report on Airport CRDF Installation*, June 1, 1951 to October 10, 1951.
18. Dunn, E.J. *CRDF Alignment Generator.*, December 15, 1952.
19. Hyneman, R.F., and Johnk, C.T. *Display and Recording Equipment for Direction-Finder Error Studies.*, June 13, 1952.
20. Hyneman, R.F. *Noise Measurements on CRDF Receiver.*, December 4, 1952.
21. Anderson, J.M. *Special Theory of Ionospheric Cross-Modulation.*, January 7, 1953.
22. Strawn, Roland S., *Descriptive Data for Pulse Generator.*, July 22, 1953.
23. O'Meara, T.R. *Alignment Data for the U. of I. Matched-Three-Channel RF Head.*, August 31, 1953.

Appendix B (Continued)

24. (Classified). December 28, 1953.
25. O'Meara, T.R. A Short German-English DF Dictionary.

Appendix C  
Task XV Publications and Miscellaneous Papers

Bouiet, J.L.L. *Investigation of Doppler Effect in Determining Direction of Arrival of Radio Waves.* Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. September 21, 1947.

Annis, R. *Antenna Arrays Having Harmonic Patterns.* Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. June 1948.

Jordan, E.C., and Myers, J.J. *Radio Direction Finding Analyzer.* Paper presented at National Electronics Conference, Chicago, Illinois. November 6, 1948.

Campbell, Richard A. *An Analysis of Phase Discriminators.* Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. August 1950.

Brunner, R.H. *Precision Measurement of Differential Phase.* Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. August 1950.

Webb, H.D. *Selecting Critical Components for Matched-Channel Radio Receiving Systems.* Proceedings of the National Electronics Conference. Volume 6. 1950 pp. 206-17.

DuHamel, R.H. *Optimum Current Distributions for Antenna Arrays with Circular Symmetry.* Paper presented at the National Institute of Radio Engineers Conference, New York, New York, March 21, 1951.

Fowler, V.J. *Transmission Line Tubes.* Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. June 1951.

Yaru, N. *A Note on Super-Gain Antennae Arrays.* Proceedings of the Institute of Radio Engineers. Volume 39, September 1951. pp. 1081-1085.

Jordan, E.C. *Antennas for Radio Direction Finding.* Paper presented at the joint meeting of URSI and IRE Professional Group on Antennae and Propagation, Washington, D. C. April 1951.

DuHamel, R.H. *Antenna Pattern Synthesis.* Research thesis submitted in partial fulfillment of the requirements for a Ph.D. Degree at the University of Illinois. September 1951.

Michel, W.E. *A System for Automatic Alignment of Matched Channel Receivers.* Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. June 1952.

O'Meara, T.R. and Webb, H.D. *Phase and Gain Stabilization in Matched Channel Receivers.* Paper presented at the National Electronics Conference, Chicago, Illinois. September 30, 1952. Proceedings of the National Electronics Conference, Volume 8, 1952. pp. 376-386

Appendix C (continued)

Peckham, Vernon Dale, *A Bearing Error Data Computer and Counter*. Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. February 1953.

Hyneman, R.F. *Pulse Display Equipment for Direction Finder Error Studies*. Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. February 1953.

DuHa sel, R.H. *Optimum Patterns for Endfire Arrays*. Proceedings of the Institute of Radio Engineers. Volume 41. May 1953. pp. 652-659.

Sydnor, R.L., *Transformation of Radio-Direction-Finder Bearing Indications from the ABI Type to the Watson-Watt Type*. Research thesis submitted in partial fulfillment of the requirements for a Master's Degree at the University of Illinois. August 1953.

Bailey, A.D., *An Investigation of the Direction of Arrival of Radio Waves*. Research thesis submitted in partial fulfillment of the requirements for a Ph.D. Degree at the University of Illinois, June 1954.

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